TURBULENCE STUDIES ON A HIGH-ALTITUDE SOUNDING AIRCRAFT

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16. Abstract

Collection of theoretical and experimental studies of convective processes, turbulence and wave propagation in the atmosphere. A review of the existing hydrodynamic models of Cumuli is given. The results of extensive studies of temperature field structures in various portions of Cumuli are also included. Other studies concern the theory of atmospheric gravitational waves, and turbulence in the stratosphere as observed in a high-altitude sounding aircraft.

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Due to the development of supersonic aircraft flying in the stratosphere, the problem has arisen of studying the phenomena which are dangerous for these aircraft, particularly turbulence.

For this purpose, the Central Aerological Observatory together with the State Scientific Research Institute of Aviation between December, 1968 and February, 1970 performed four surveys in a high-altitude subsonic aircraft. Sensors of EA-20 and MP-66 type were used to record the aircraft overloads. The overloads were recorded by means of the optical K-20-21 automatic recording instrument.

The flights of the high-altitude sounding aircraft were carried out in the region of Sukhumi in horizontal areas at altitudes of 10-18 km. The pilot maintained the aircraft control lever in a fixed position as far as possible, when in these areas.

To calculate the turbulence coefficient (k) characterizing the intensity of turbulence, cases were selected with overload increments of great duration (no less than 30 c) and magnitude $(\geq 0.1g)$.

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* Numbers in margin indicate pagination in original foreign text.

The turbulence coefficient was calculated according to the Lyapin-Dubov formula, which was refined by German [1]

$$k = \frac{v\,\overline{|w|}\,\overline{\Delta\tau}}{2\eta}, \tag{1}$$

where v— is the average flight velocity in a given area m/c; $\overline{|w|}$ — absolute average velocity of the vertical air gusts m/c; $\overline{\Delta\tau}$ — average conservation time of the velocity pulsation sign, c; η— transmission function for the given type of aircraft.

The vertical air gust velocity w, with allowance for the vertical velocity of the aircraft center of gravity and the change in the pitch angle, was calculated according to the formula

$$w = \Delta v_z + b\Delta n - v\Delta\varphi, \tag{2}$$

where v_z is the vertical velocity of the aircraft center of gravity, produced as a result of the gust, and equals $v_z = g\int \Delta n\,dt$; / 87
φ — pitch angle, rad; Δv_z and $\Delta\varphi$ — deviations from the average aircraft vertical velocity and the pitch angle, respectively; v— horizontal velocity of the aircraft; b— coefficient depending on the aerodynamic characteristics of the aircraft and the flight velocity

$$b = \frac{2G/S}{c^{\alpha}_{y}\rho_H v^2},$$

where G— is the aircraft weight; S— wing area; c^{α}_{y} — derivative of the lift force coefficient with respect to angle of attack; ρ_H— density at flight altitude; v— flight velocity.

During the calculation of the coefficient b, the change in the aircraft weight due to fuel consumption was taken into account. Table 1 gives values of the turbulence coefficient which were calculated for seven sections during three flights.

The vertical gradients of temperature (γ) and wind velocity (β) were calculated for the ±250 m layer from the flight level. The aerosynoptic characteristics of the flight conditions for the cases included in Table 1 are given below. Figure 1 gives the vertical profiles of temperature and wind based on sounding data for 15 hours over the region Mineralynyye Vody on 24 and 27 December, 1968 (a,b) and over Sukhumi on 21 April, 1969 (c).

Flight on 24 December 1968.

There was a high altitude frontal zone on 24 December in the upper troposphere above the Caucasus. There was a jet stream along this zone, whose axis was located above the Sukhumi region at wind velocities of about 50 m/c in the 300-200 mb layer. To the north there was divergence of the isohypse with a gradual change to anticyclonic curvature. The wind shifted along the stream. On the $OT_{500/1000}$ map in this region there were considerable temperature contrasts between a hot region in the southeast and a cold region in the west. The tropopause sharply increased from the west to the east. Above Sukhumi it was located at a level of 203 mB with a temperature of – 64° C. /89

At the 200 and 100 mB levels the flight passed through the forward part of a trough—the rear section of the crest. It is probable that there was divergence of the air flow — significant displacements of the wind along the flow and perpendicular to it — and large vertical gradients of the wind contributed to the formation of turbulence in this layer.

As may be seen from Table 1, turbulence was observed at the 11.5 and 12.4 km altitudes. In each of the two areas, the turbulent zones extended from 5500 to 11,080 m. The overloads fluctuated between 0.53 to — 0.30 g. Unfortunately in the first area the pitch angle was not recorded. Therefore, the value of k was calculated according to formula (2).

TABLE 1*

Date	H км	k м²/с	γ°/100 м	β м/с/100 м
24 XII 1968	11,15	92	0,07	−1,90
24 XII 1968	11,15	121	0,07	−1,90
24 XII 1968	12,4	175	0,07	−0,55
24 XII 1968	12,4	242	0,07	−0,55
27 XII 1968	11,0	32	−1,17	−0,30
27 XII 1968	11,0	52	−1,17	−0,30
21 IV 1969	13,5	63	−0,25	−0,70

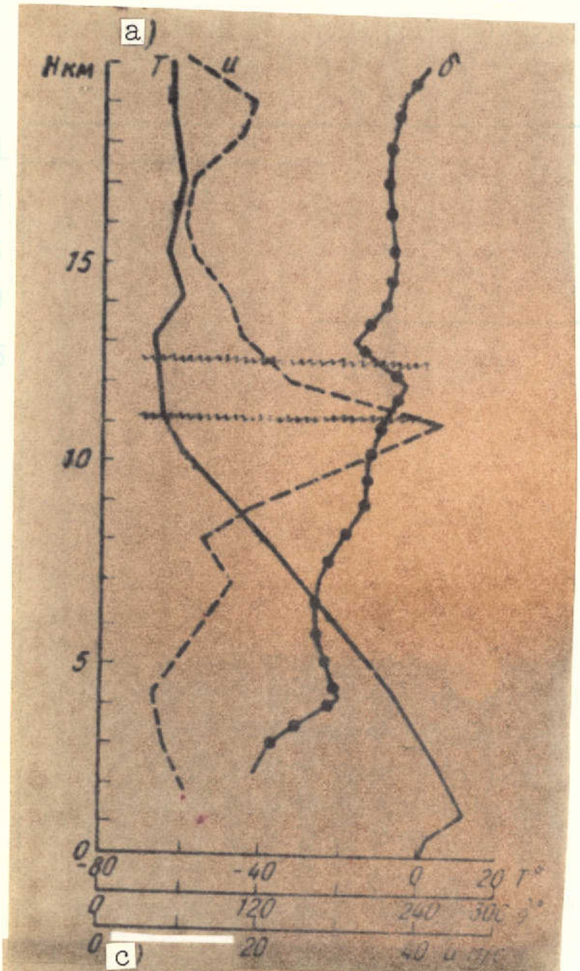
* Translator's note: Commas in numbers represent decimal points

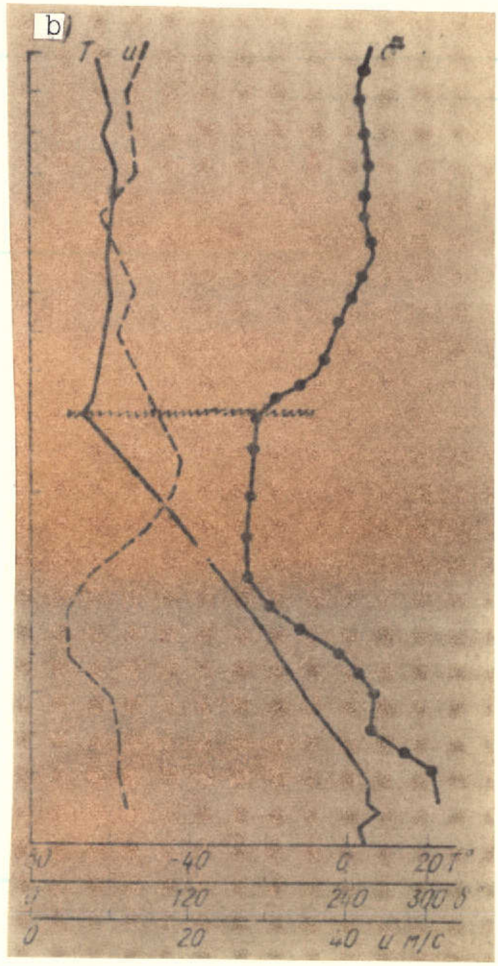
without allowance for the third component.

As may be seen from the figure, the first two turbulence zones (k=92 and 121 m^2/c) were located close to the base of the tropopause layer in a layer with a rapid decrease in the wind velocity (γ =0.07°/100 m and β = -1.90 m/c/100 m). In the second area, the values of the turbulence coefficient were two times greater (k = 175 and 242 m^2/c). They refer to a layer of a slow decrease in temperature and wind velocity with altitude (γ= -1.17°/100m and β= -0.55 m/c/100 m), but in a zone of a sharp wind rotation (4.0°/100 m).

<u>Flight on 27 December 1968.</u>

There was a slightly moving front with waves on the surface of the Earth above the southeastern Black Sea and the Caucasus in a small-gradient baric field. In the troposphere, the flight region was close to the axis of a trough extending from the northwest to the southeast. The wind moved in a southeastern direction in the forward part of the trough at the 300 mb level. There was convergence of the air flow. The axis of the jet





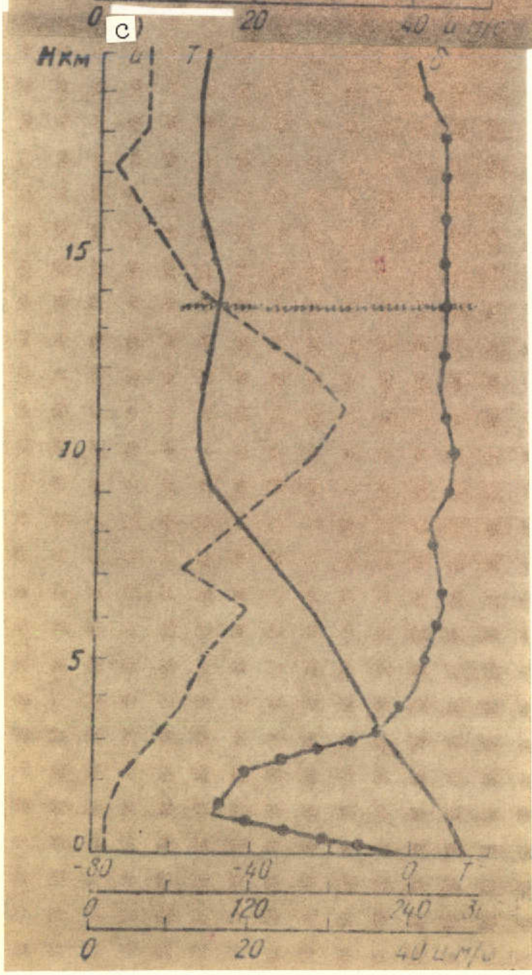


Figure 1. Vertical profiles of temperature and wind based on sounding data:

a- 24 December; b- 27 December 1968; c- 21 April 1969; T- temperature curve; u and δ- curves for wind velocity and direction, respectively; above 10 km - turbulence zone.

stream passed from the south to the north of the Black Sea and lateral wind displacements were produced in the flight region on the anticyclonic side. There was a significant change in the wind direction with altitude in the stratosphere. At an altitude of 11,500 meters the wind moved in a southwestern direction 20 m/c and at an altitude of 16,000 m— in a southwest-west direction 10 m/c.

As may be seen from Table 1, the values of the turbulence coefficient were determined for an altitude of 11 km for two zones extending 1990 and 6330 m. The overload increments changed from 0.21 to -0.16. The values of the turbulence coefficients were 32 and 52 m^2/c in the layer of a sharp temperature change ($\gamma = -1.17°/100$ m) with a vertical wind gradient $\beta = -0.30$ m/c/100 m. In this layer there was wind rotation $\approx 2{,}5°/100$ м.

Flight on 21 April 1969.

The flight region in the troposphere was under the influence of the delta of a frontal zone extending from the west to the east on the southern periphery of a high cyclone with the center in the Varshav region. In the lower stratosphere the wind moved in a southwestern direction, which changed to a western direction with altitude. The flight passed along the cyclonic side of the jet stream. In this flight turbulence was observed at an altitude of 13.5 km. The turbulent zone extended for 8,550 m, and the overload increment equals 0.31 - 0.22g. This zone was located in a layer with a small temperature increase ($\gamma = -0.25°/100$m) and a large negative wind velocity gradiant ($\beta = -0.70$ m/c/100 m).

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Based on the cases analyzed, turbulence was observed in the zone of the tropopause, in the zone of a sharp temperature decrease or a wind velocity decrease. The greatest values of the turbulence coefficients were reached in a zone of sharp wind rotation.

REFERENCES

1. German, M. A. Turbulent Exchange in Clouds. Meteorologiya i gidrologiya, No. 10, 1963.

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